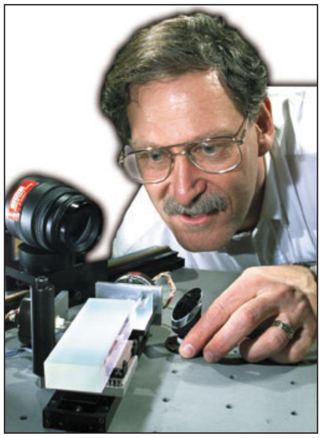
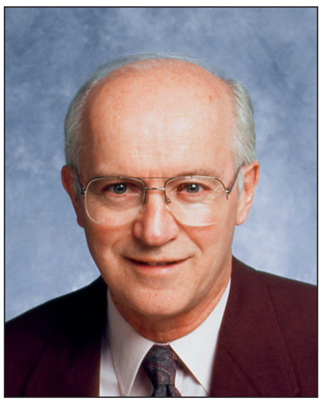
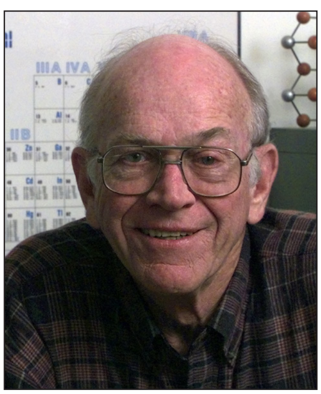
2015 Arthur H. Compton Award







Top to bottom: Gene E. Ice, Bennett C. Larson, and Cullie J. Sparks

The 2015 APS Arthur H. Compton Award has been awarded to Gene E. Ice, Bennett C. (Ben) Larson, and Cullie J. Sparks (posthumously), all of Oak Ridge National Laboratory, for seminal developments that have advanced capabilities for spatially and temporally resolved synchrotron x-ray research.

The nomination recognizes transformative breakthroughs in three areas: (1) techniques for using single synchrotron pulses for ultrafast time-resolved diffraction studies; (2) focusing monochromators for producing small, intense synchrotron x-ray beams; and (3) x-ray microscopy with three-dimensional, submicron spatial resolution. The impact of these breakthroughs has been important not only at the Advanced Photon Source but also at light sources worldwide.

The three researchers exploited the high brilliance and intrinsic pulsed time-structure of synchrotron sources to create techniques and instrumentation that are now considered indispensible tools for x-ray science. "With their vision, their deep understanding of the interaction of x-rays with matter, and their exquisite experimental skills, they paved the way to the modern instrumentation of today's large-scale x-ray facilities," said Helmut Dosch, chair of the board of directors of DESY in Hamburg, Germany.

Time-resolved studies

Ben Larson and his colleagues were the first to couple single synchrotron x-ray pulses with pulsed-laser excitations to perform single x-ray pulse x-ray diffraction measurements. This strategy yielded nanosecond time resolution for materials studies. Larson's seminal experiments [1,2] clarified the mechanism of pulse-laser-induced melting in silicon, thereby resolving a significant controversy. The technique has been adapted to both polychromatic and monochromatic applications at the APS and enables diffraction and spectroscopy to investigate the evolving structure of materials on ultrashort time scales.

Simple in hindsight, this technique immediately transformed synchrotron time-resolved diffraction from measurements limited by detector gating capabilities and time-average intensities to measurements with a temporal resolution determined by the ~100 picosecond synchrotron pulse widths. In addition, the technique had the inherent advantage of the ultrahigh instantaneous intensities available during individual pulses. This now-common technique represents a core capability at the APS and on third- and fourth-generation pulsed x-ray sources in general, and it has opened the way to studies at femtosecond time scales at free-electron laser facilities.

Precision focusing optics

Cullie Sparks and Gene Ice pioneered the use of dynamically bent curved crystals to simultaneously focus and monochromatize synchrotron x-rays, a technique called sagittal focusing [3,4]. The result was a small, ultra-intense, and tunable monochromatic beam that made it possible to study a new range of weakly scattering samples.

At the time, the idea that monochromator crystals could be bent with sufficient accuracy to focus beams was considered impractical; the crystals would take a saddle shape (anticlastic bending) instead of a single curve. Sparks and Ice found that they could prevent this distortion by cutting ribs on the back of the crystal parallel to the plane of scattering. Solving the otherwise fatal obstacle of anticlastic bending turned sagittal focusing from a theoretical curiosity into a deployable technology—which has now become standard instrumentation. Optics of this type are in use in at least five bending magnets and four insertion device beamlines at APS and on other beamlines at synchrotrons worldwide, and the impact of focused beams continues to grow for studies in materials structure and dynamics, geophysics, environmental science, biophysics, and protein crystallography [5].

Three-dimensional x-ray microscopy (3DXM)

Gene Ice and Ben Larson, together with colleagues, made advances on three fronts—optics development, experimental geometry, and pattern analysis techniques—to allow submicron-resolution, three-dimensional mapping of heterogeneous microstructures in single-crystal and polycrystalline materials [6, 7]. The technique makes it possible to nondestructively measure the local structure, crystallographic orientation, grain size, grain morphology, and strain in three dimensions with a resolution of less than one micron (micrometer) over areas ranging from a fraction of a micron to hundreds of microns.

Known also as differential aperture x-ray microscopy (DAXM) because of the depth profiling principle, 3DXM depends on the use of an x-ray–absorbing wire that is moved stepwise across the diffraction pattern. Differences in pixel intensities at each step are analyzed by powerful computer-cluster-based analysis programs. The result is that a full diffraction pattern is extracted from individual submicron-sized volume elements—without rotating the sample. The method was demonstrated in 1999 on sector 7, prototyped at a dedicated facility on sector 34 in 2001, and further developed by the APS into a 3D microprobe facility that is now available to general users.

The possible applications of DAXM are enormous [8], because virtually all technologically important materials and advanced processing techniques are based on the generation of heterogeneous microstructures or heterostructure at interfaces between materials. Thus, applications range from analyzing strains and identifying defects in microelectronic devices, to detailing the processes that occur during forge processing of structural alloys, to drug design, to environmental and geological studies. In the context of the APS, the 3DXM facility at sector 34 provides an important bridge between the nanoscale capabilities at sector 26 and the penetrating, high-energy diffraction three-dimensional microscopy at sector 1. As a result, the APS is able to offer nondestructive 3D microscopy from the nanoscale to the macroscale.

References

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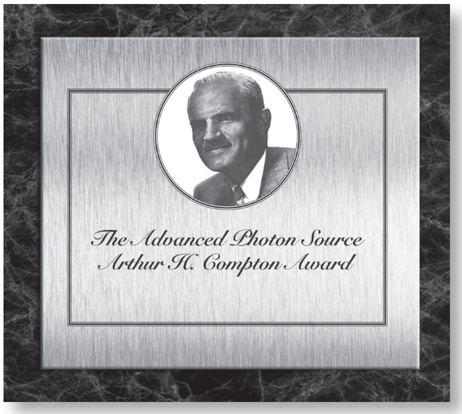
About the Award



The Arthur H. Compton award was established in 1995 by the APS Users Organization (APSUO) to recognize an important scientific or technical accomplishment at the Advanced Photon Source. The awards are generally made at APS User Meetings.

Compton was an American physicist who won the Nobel Prize for Physics in 1927 for discovering and explaining changes in x-ray wavelengths resulting from x-ray collisions with electrons, the so-called Compton effect. This important discovery in 1922 confirmed the dual nature (wave and particle) of electromagnetic radiation. A Ph.D. from Princeton University, Compton held many prominent positions including professor of physics at The University of Chicago and chairman of the committee of the National Academy of Sciences that studied the military potential of atomic energy. His position on that committee made Compton instrumental in initiating the Manhattan Project, which created the first atomic bomb.

Previous award recipients
Nikolai Vinokurov and Klaus Halbach (1995)
Philip M. Platzman and Peter Eisenberger (1997)
Donald H. Bilderback, Andreas K. Freund, Gordon S. Knapp, and Dennis M. Mills (1998)
Sunil K. Sinha (2000)
Wayne A. Hendrickson (2001)
Martin Blume, L. Doon Gibbs, Denis McWhan, and Kazumichi Namikawa (2003)
Günter Schmahl and Janos Kirz (2005)
Andrzej Joachimiak and Gerold Rosenbaum (2007)
Gerhard Grübel, Simon Mochrie, and Mark Sutton (2009)
Edward Stern, Farrel Lytle, Dale Sayers (posthumously), and John Rehr (2011)
David E. Moncton, John N. Galayda, Michael Borland, and Louis Emery (2013)